PATENT SPECIFICATION (11) 1 468 710

1 468 710

(21) Application No. 18981/74 (22) Filed 30 April 1974 (19)

(23) Complete Specification filed 30 April 1975

(44) Complete Specification published 30 March 1977

(51) INT. CL.[2] B21D 53/02

(52) Index at acceptance

B3A 122J 122M 122X 158
B3M 17X 19B 3X 7X
B3Q 2A6 2H
F4S 2M2 4E2C

(72) Inventor HENRY LLOYD

(54) IMPROVEMENTS IN OR RELATING TO METHODS OF FORMING RE-ENTRANT CAVITIES IN THE SURFACE OF HEAT EXCHANGE MEMBERS OR EBULLATORS

(71) We, UNITED KINGDOM ATOMIC ENERGY AUTHORITY, 11 Charles II Street, London, S.W.1, a British Authority, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to forming re-entrant cavities in heat exchange members or ebullators for assisting boiling of liquids such as for example cryogenic liquids.

It is well known that boiling of a liquid in contact with a heated wall takes place by bubbles appearing and departing from discrete locations upon the surface. It is also well known that these bubbles form at minute unwetted cavities, imperfections, or scratches in the surface of the wall, which occur naturally, or are formed intentionally. Surfaces provided with such bubble nucleation sites, as these cavities are known, give rise to much better heat transfer rates than smooth clean surfaces.

Nucleation sites assist boiling of liquids by initially allowing a small amount of gas, such as for example air, to be trapped in the cavity as the surface of the wall is initially covered by the liquid to be boiled. Only cavities which are not wetted by the liquid can serve as active nucleation sites. The size and geometry of the cavity in relation to the nature of the surface, the liquid, and other parameters, also dictates whether a particular site will become active or not.

The gas initially trapped in the cavity, at incipient bubble nucleation, is gradually replaced by the vapour of the liquid being boiled. The vapour then serves to encourage further nucleation and therefore continuous evaporation takes place at the active nucleation sites. This process carried on until the cavity becomes wetted by the liquid, such as for example as might occur under some circumstances such as by allowing the temperature of the liquid to be boiled to fall below the saturation temperature of the liquid. Upon this happening the advantages of nucleated boiling are lost.

It is known that re-entrant cavities, that is to say a cavity with a smaller opening presented to the bulk of the liquid than the size of the main cavity, have superior nucleation properties to that of non-re-entrant cavities. Re-entrant cavities remain filled with vapour even when boiling ceases and thus more stable nucleation sites can be formed which are not "snuffed out" as gas diffuses out or vapour condenses within the cavity.

Ebullators are also well known, see for example U.S. Patent No. 1,931,268. Ebullators are devices which although not heated directly (they can in fact be thermally non conductive) are placed in liquids to be boiled so as to provide convenient nucleation sites for bubble formation within the bulk of the liquid.

Many techniques have been employed in the past in order to provide nucleation sites on a heated wall, or on ebullators. For example it is known to machine micro-grooves in the surface of a wall to be heated as mentioned in British Patents, 1,195,383 and 1,260,170. Again it is known to bond powder particles to a heat exchange wall to be heated, or to a metal base to form an ebullator, so as to leave suitable cavities between the particles (see for example British Patents 1,267,139, 1,267,149 and 1,222,038).

An object of the present invention is to provide a method of forming re-entrant nucleation sites in a surface of a heat exchange member or an ebullator.

According to the present invention there is provided a method of forming re-entrant

cavities in a heat exchange member or an ebullator member comprising the steps of piercing a surface of the member with one or more spikes to form discrete holes in the surface of the member, and working the member to close partially the holes and thereby form re-entrant cavities in the member.

The spike or spikes may be carried by a platen or a roller.

The step of working the member to partially close the indentations may comprise rolling a plain surfaced roller over the surface of the member in which the indentations are formed.

The member may be a hollow tube in which case the indentations may be formed on at least part of the inside or outside surfaces of the tube.

The member may be a strip or flat sheet of metal. The strip or flat sheet of metal may be shaped to a tubular shape and seam welded to produce a tube.

According to a further aspect of the invention a heat exchange member or an ebullator member is provided with re-entrant cavities formed in accordance with the method of the present invention.

An embodiment of the invention will now be described with reference to the drawings accompanying the Provisional Specification. in which,

Figure 1 illustrates a cross-sectional view through a strip of metal in which cavities are indented into a surface of the strip, and

Figure 2 illustrates a cross-sectional view of the strip of Figure 1 after it has been worked to partially close the indentations.

Referring to Figure 1 there is shown a strip 10 of aluminium alloy typically 1.5 mm thick and of any desired width and length. The strip is intended to be subsequently shaped into a tubular shape and seam welded to form a hollow heat exchanger tube with the re-entrant cavities in the internal surface of the tube.

Indentations 11 are formed in the strip by passing the strip between a spiked roller 12 and a plain roller 13 or by using a spiked platen (not shown) which is pressed into the strip 10. The spikes 14 on the roller 12 or platen are typically conical and are dimensioned so as to produce the required size of indentations in the strip (typically having a mean diameter of 50 to 150 μ). The indentations in the strip 10 are approximately the same shape as the spikes 14 but material of the strip is back-extruded to leave slight mounds 15 adjacent each indentation.

The strip 10 is then passed through the nip of two rolls 16, 17 (see Figure 2) so as to work the indentations 11 and cause the mounds 15 adjacent each indentation to partially close off each indentation. In this way indentation 11 is converted into a re-entrant cavity as shown in Figure 2. Each re-entrant cavity comprises a mouth portion 18 presented to the bulk of the liquid which is of a smaller cross-sectional area than that of the main cavity 19.

The strip 10 with its re-entrant cavities 19 is subsequently shaped into a tubular shape and seam welded to form a hollow tube.

Instead of fabricating the strip 10 into a tube after the re-entrant cavities have been formed, one may fabricate the strip into a tube after the indentations 11 are formed in it, but before the strip is worked to partially close the indentations. In this latter case, the completed tube may be worked, for example by passing it through shaped rolls or dies, or swaged onto a temporary mandrel inside the tube using a planetary ball swage of the type described in our British Patents 946,407 and 987,988.

In operation, a liquid to be boiled, for example a cryogenic liquid is caused to flow through the bore of the tube and a heating medium is caused to flow over the outside of the tube.

Instead of fabricating the tube from a seam welded strip of metal, the tube may be a seamless tube in which the re-entrant cavities are formed in the tube by using a spiked roller which is smaller than the bore of the tube and which is caused to rotate eccentrically in the bore of the tube.

The re-entrant cavities may be formed in the outside surface of the tube.

Instead of using the strip 10 to make a heat exchange wall, the strip may be used to make an ebullator. In this case the strip need not be made of thermally conductive material and could in fact be a ceramic material.

The strip 10 may be twisted so as to form a ribbon type ebullator.

The re-entrant cavities so formed form nucleation sites which assist in boiling liquids that contact them in the manner discussed above.

Preferably the size of the re-entrant cavities lie in the range of 4 μ to 40 μ diameter at the mouth portion 18 (sometimes called the throat) and typically 50 μ to 150 μ diameter at the main cavity 19.

WHAT WE CLAIM IS:—

1. A method of forming re-entrant cavities in a heat exchange member or an ebullator member comprising the steps of piercing a surface of the member with one or more spikes to form discrete holes in the surface of the member, and working the member to close partially the holes and thereby form re-entrant cavities in the member.

2. A method according to claim 1

wherein the spike or spikes are carried by a platen.

3. A method according to claim 1 wherein the spike or spikes are carried by a roller.

4. A method according to any one of the preceding claims wherein the step of working the member to partially close the holes comprises rolling a plain surfaced roller over the surface of the member in which the holes are formed.

5. A method according to any one of the preceding claims wherein the member is a hollow tube and the holes are formed on at least part of the inside surface of the tube.

6. A method according to any one of claims 1 to 4 wherein the member is a hollow tube and the holes are formed on at least part of the outside surface of the tube.

7. A method according to any one of claims 1 to 4 wherein the member is a sheet of metal.

8. A method according to claim 7 wherein the sheet is wound into a tubular shape and is seam welded to form a tube.

9. A heat exchanger member provided with re-entrant cavities formed by the method claimed in any one of the preceding claims.

10. An ebullator provided with re-entrant cavities formed by the method claimed in any one of the preceding claims 1 to 8.

11. A method of forming re-entrant cavities in a heat exchange member or an ebullator member substantially as herein described with reference to the drawings accompanying the Provisional Specification.

K. LEAMAN,
Chartered Patent Agent,
Agent for the Applicants.

Printed for Her Majesty's Stationery Office by Burgess & Son (Abingdon), Ltd.—1977.
Published at The Patent Office, 25 Southampton Buildings, London, WC2A 1AY
from which copies may be obtained.

1468710 PROVISIONAL SPECIFICATION
1 SHEET *This drawing is a reproduction of the Original on a reduced scale*

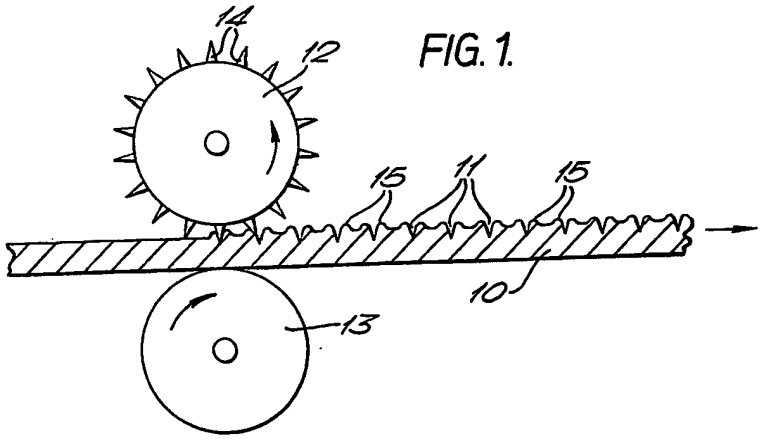

FIG. 1.

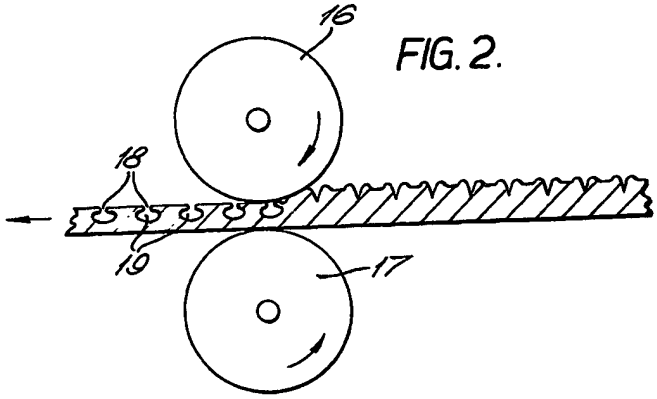

FIG. 2.